Piezoelectric and mechanical properties of a high performance thermoplastic composite

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Introduction

To protect aircraft and satellite structures from mechanical solicitations such as vibrations, a piezoelectric-based passive damping concept is studied. Most of the time, the piezoelectric elements are surface bonded or embedded in the host structure that needs to be damped. There are integrated with an external shunted circuit. When the piezoelectric material is deformed, it generates an electrical potential that is dissipated by Joule effect in a resistive element.

More precisely, the purpose of this work is to integrate this passive macroscopic damping concept to the composite scale. For this, a hybrid piezoelectric composite based on high performance thermoplastic polymer as structural matrix is developed. This structural matrix belongs to the PAEK (Poly Aryl Ether Ketone) family. The high glass transition temperature of these thermostable polymers is a critical parameter in the choice of the piezoelectric ceramic. Its Curie temperature has to be higher than the Tg of the composite. In addition, one of the main challenges is to ensure homogeneous particle dispersion with a sufficiently low content to maintain the matrix ductility. We propose to present the piezoelectric and mechanical properties of a thermoplastic polymer / micronic piezoelectric particle composites as a function of their chemical composition.

Experimental

Ferroelectric particles were elaborated by hydrothermal synthesis in an autoclave during a few hours. Scanning Electron Microscopy images of ceramic powder are shown in fig. 1. The size of the piezoelectric particles is about 1 µm. Particles are cubic so they have a low aspect ratio. Ceramic and polymer powders are mixed and dispersed in ethanol with ultrasounds. After evaporation of the solvent the composite powder is homogenous. Composites were elaborated using a twin-screw extruder and uniaxial press to make thin films with different volume fraction: i.e. from 5%v, to 40%v. SEM images of a composite film are also shown in fig. 2. The particle dispersion looks to be homogeneous.

Results

In order to measure the high Curie temperature Tc of piezoelectric particles a non-classical protocol has been used. A ceramic disk was manufactured by compression and sintered. The sample was polarized and annealed at different temperatures. The d_{33} evolution was determined as a function of annealing temperature. The particles Curie temperature will be discussed regards to the literature one.

The composites piezoelectric coefficient increases with the piezoelectric particles volume fraction. Composite polarization step is essential to give the macroscopic piezoelectric property. Poled parameters (electrical field, temperature, time) have been optimized to improve the piezoelectric coefficient.

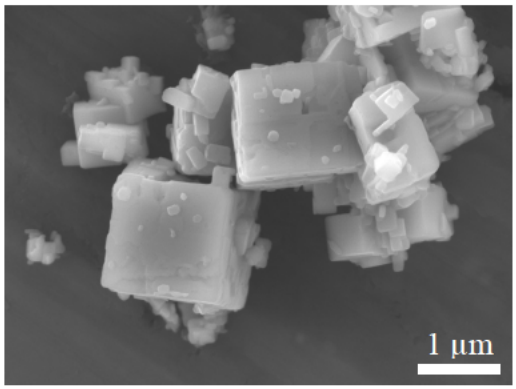

Fig. 1 *SEM image of ceramic powder.*

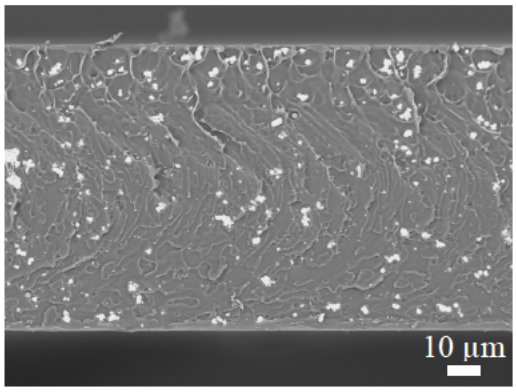

Fig. 2 *SEM image of a composite cryocut with 5%v of particles.*

Hybrid high performance thermoplastic composites were processed and their dynamic moduli were determined by dynamical mechanical analyses in torsional mode. One of the objectives of this work is to study, in parallel of the composite mechanical properties, the evolution of the piezoelectric coefficient as a function of the ceramic particles volume fraction. Even if the literature clearly mentions that this coefficient increases with the ceramic content, it is essential to keep this last sufficiently low to avoid a change in composite connectivity and induce dramatically modifications of the matrix mechanical properties.

Conclusions

High Tc piezoelectric particles have been elaborated and dispersed in a thermostable thermoplastic matrix. The ability of this new kind of composites to reach a significant piezoelectric coefficient while maintaining the mechanical properties of the polymeric matrix will be discussed.

References

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